

K/ER-218

Environmental Restoration Program Division  
K-25 Environmental Restoration Program

**Radiological Characterization of Inactive Waste Sites  
at the Oak Ridge K-25 Site, Oak Ridge, Tennessee**

**Volume 1 of 6**

Date Issued—May 1995

Prepared by  
CDM Federal Programs Corporation  
Oak Ridge, Tennessee 37830  
under contract 96B-99052C  
Document Control No. 7909-004-FR-BCJC

Prepared for  
U.S. Department of Energy  
Environmental Management and Enrichment Facilities  
under budget and reporting codes EU 20 and EW 20

Oak Ridge K-25 Site  
Oak Ridge, Tennessee 37831-7101  
managed by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U.S. DEPARTMENT OF ENERGY  
under contract DE-AC05-84OR21400

Energy Systems Environmental Restoration Program  
K-25 Environmental Restoration Program

**Radiological Characterization  
of Inactive Waste Sites  
at the Oak Ridge K-25 Site,  
Oak Ridge, Tennessee**

**Volume 1 of 6**

Date Issued—May 1995

Prepared by  
CDM Federal Programs Corporation  
Oak Ridge, Tennessee 37830  
under contract 96B-99052C  
Document Control No. 7909-004-FR-BCNS

Prepared for  
U.S. Department of Energy  
Office of Environmental Restoration and Waste Management  
under budget and reporting code EW 20

OAK RIDGE K-25 SITE  
Oak Ridge, Tennessee 37831  
managed by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U.S. DEPARTMENT OF ENERGY  
under contract DE-AC05-84OR21400

This document has been approved for release  
to the public by:

*Archie D. Smith* 6/16/95  
Technical Information Officer Date  
Oak Ridge K-25 Site

# CONTENTS

FIGURES .....	xi
TABLES .....	xix
ABBREVIATIONS .....	xxvii
PREFACE .....	xxix
EXECUTIVE SUMMARY .....	xxxi
 1. INTRODUCTION .....	 1-1
1.1 OBJECTIVE .....	1-2
1.2 APPROACH TO RADIOLOGICAL CHARACTERIZATION .....	1-2
1.2.1 Qualitative Approach—Radiological Survey .....	1-2
1.2.2 Quantitative Approach—Surface Soil Sampling .....	1-5
 2. RADIOLOGICAL CHARACTERIZATION PROCEDURES .....	 2-1
2.1 RADIOLOGICAL SURVEY PROCEDURES .....	2-1
2.1.1 Description of the Ultrasonic Ranging and Data System .....	2-1
2.1.2 Instrumentation .....	2-2
2.1.3 Survey Procedures .....	2-4
2.1.4 Survey Data and Maps Generated .....	2-7
2.2 SOIL SAMPLING PROCEDURES .....	2-9
2.3 ANALYTICAL METHODS .....	2-10
2.4 QUALITY CONTROL MEASURES .....	2-10
2.4.1 Radiological Survey Quality Control .....	2-10
2.4.2 Soil Sampling Quality Control .....	2-12
 3. ENERGY SYSTEMS SOIL CONTAMINATION GUIDELINES .....	 3-1
3.1 PURPOSE OF SOIL CONTAMINATION GUIDELINES .....	3-2
3.2 DEVELOPMENT OF SOIL CONTAMINATION GUIDELINES .....	3-2
3.3 IMPLEMENTATION OF SOIL CONTAMINATION GUIDELINES .....	3-4
 4. SITE-SPECIFIC CHARACTERIZATION .....	 4-1
4.1 K-1131 NEUTRALIZATION PILE .....	4.1-1
4.1.1 Physical Description/Survey Setup .....	4.1-1
4.1.2 Nature and Extent of Radiological Contamination .....	4.1-1
4.1.3 Data Interpretation .....	4.1-5
4.1.4 Significance of Findings .....	4.1-5
4.1.5 Radiological Survey Maps .....	4.1-5
4.2 K-1232 CHEMICAL RECOVERY FACILITY (LAGOON AREA) .....	4.2-1
4.2.1 Physical Description/Survey Setup .....	4.2-1
4.2.2 Nature and Extent of Radiological Contamination .....	4.2-1
4.2.3 Data Interpretation .....	4.2-4
4.2.4 Significance of Findings .....	4.2-4
4.2.5 Radiological Survey Maps .....	4.2-4
4.3 K-631 CONTAMINATED SOIL .....	4.3-1
4.3.1 Physical Description/ Survey Setup .....	4.3-1

4.3.2	Nature and Extent of Radiological Contamination	4.3-1
4.3.3	Data Interpretation	4.3-5
4.3.4	Significance of Findings	4.3-6
4.3.5	Radiological Survey Maps	4.3-6
4.4	K-1070-A LANDFARM	4.4-1
4.4.1	Physical Description/Survey Setup	4.4-1
4.4.2	Nature and Extent of Radiological Contamination	4.4-1
4.4.3	Data Interpretation	4.4-6
4.4.4	Significance of Findings	4.4-6
4.4.5	Radiological Survey Maps	4.4-6
4.5	K-1070-A OLD CONTAMINATED BURIAL GROUND	4.5-1
4.5.1	Physical Description/Survey Setup	4.5-1
4.5.2	Nature and Extent of Radiological Contamination	4.5-1
4.5.3	Data Interpretation	4.5-7
4.5.4	Significance of Findings	4.5-7
4.5.5	Radiological Survey Maps	4.5-7
4.6	K-895 CYLINDER DESTRUCT FACILITY	4.6-1
4.6.1	Physical Description	4.6-1
4.6.2	Nature and Extent of Radiological Contamination	4.6-1
4.6.3	Data Interpretation	4.6-7
4.6.4	Significance of Findings	4.6-7
4.6.5	Radiological Survey Maps	4.6-7
4.7	K-901-A HOLDING POND	4.7-1
4.7.1	Physical Description/Survey Setup	4.7-1
4.7.2	Nature and Extent of Radiological Contamination	4.7-1
4.7.3	Data Interpretation	4.7-2
4.7.4	Significance of Findings	4.7-2
4.7.5	Radiological Survey Maps	4.7-3
4.8	K-901-A NORTH WASTE DISPOSAL AREA	4.8-1
4.8.1	Physical Description/Site Setup	4.8-1
4.8.2	Nature and Extent of Radiological Contamination	4.8-1
4.8.3	Data Interpretation	4.8-12
4.8.4	Significance of Findings	4.8-12
4.8.5	Radiological Survey Maps	4.8-13
4.9	K-901-A SOUTH WASTE DISPOSAL AREA	4.9-1
4.9.1	Physical Description/Survey Setup	4.9-1
4.9.2	Nature and Extent of Radiological Contamination	4.9-1
4.9.3	Data Interpretation	4.9-3
4.9.4	Significance of Findings	4.9-3
4.9.5	Radiological Survey Maps	4.9-3
4.10	K-1070-F CONSTRUCTION SPOIL AREA	4.10-1
4.10.1	Physical Description/Survey Setup	4.10-1
4.10.2	Nature and Extent of Radiological Contamination	4.10-1
4.10.3	Data Interpretation	4.10-4
4.10.4	Significance of Findings	4.10-4
4.10.5	Radiological Survey Maps	4.10-5

4.11	DUCT ISLAND ROAD .....	4.11-1
4.11.1	Physical Description/Survey Setup .....	4.11-1
4.11.2	Nature and Extent of Radiological Contamination .....	4.11-1
4.11.3	Data Interpretation .....	4.11-10
4.11.4	Significance of Findings .....	4.11-10
4.11.5	Radiological Survey Maps .....	4.11-10
4.12	K-770 CONTAMINATED DEBRIS AND SCRAP METAL YARD .....	4.12-1
4.12.1	Physical Description/Survey Setup .....	4.12-1
4.12.2	Nature and Extent of Radiological Contamination .....	4.12-1
4.12.3	Data Interpretation .....	4.12-37
4.12.4	Significance of Findings .....	4.12-37
4.12.5	Radiological Survey Maps .....	4.12-37
4.13	K-709 SWITCHYARD .....	4.13-1
4.13.1	Physical Description/Survey Setup .....	4.13-1
4.13.2	Nature and Extent of Radiological Contamination .....	4.13-1
4.13.3	Data Interpretation .....	4.13-6
4.13.4	Significance of Findings .....	4.13-6
4.13.5	Radiological Survey Maps .....	4.13-6
4.14	K-710 SLUDGE BEDS AND IMHOFF TANKS .....	4.14-1
4.14.1	Physical Description/Survey Setup .....	4.14-1
4.14.2	Nature and Extent of Radiological Contamination .....	4.14-1
4.14.3	Data Interpretation .....	4.14-3
4.14.4	Significance of Findings .....	4.14-3
4.14.5	Radiological Survey Maps .....	4.14-3
4.15	FERCLEVE/THOMPSON ROADS GAS STATION .....	4.15-1
4.15.1	Physical Description/Survey Setup .....	4.15-1
4.15.2	Nature and Extent of Radiological Contamination .....	4.15-1
4.15.3	Data Interpretation .....	4.15-2
4.15.4	Significance of Findings .....	4.15-2
4.15.5	Radiological Survey Maps .....	4.15-2
4.16	K-1251 OLD BARGE AREA .....	4.16-1
4.16.1	Physical Description/Survey Setup .....	4.16-1
4.16.2	Nature and Extent of Radiological Contamination .....	4.16-1
4.16.3	Data Interpretation .....	4.16-2
4.16.4	Significance of Findings .....	4.16-2
4.16.5	Radiological Survey Maps .....	4.16-2
4.17	K-770 NEW BARGE AREA .....	4.17-1
4.17.1	Physical Description/Survey Setup .....	4.17-1
4.17.2	Nature and Extent of Radiological Contamination .....	4.17-1
4.17.3	Data Interpretation .....	4.17-2
4.17.4	Significance of Findings .....	4.17-2
4.17.5	Radiological Survey Maps .....	4.17-2
4.18	K-1085 OLD FIREHOUSE BURN AREA, RUBBLE PILE, AND BURN PIT AREA .....	4.18-1
4.18.1	Physical Description/Survey Setup .....	4.18-1
4.18.2	Nature and Extent of Radiological Contamination .....	4.18-1
4.18.3	Data Interpretation .....	4.18-6

4.18.4	Significance of Findings .....	4.18-6
4.18.5	Radiological Survey Data Maps .....	4.18-6
4.19	K-1070 RUBBLE PILE (K-25 SITE DEMOLITION MATERIALS PLACEMENT AREA) .....	4.19-1
4.19.1	Physical Description/Survey Setup .....	4.19-1
4.19.2	Nature and Extent of Radiological Contamination .....	4.19-1
4.19.3	Data Interpretation .....	4.19-3
4.19.4	Significance of Findings .....	4.19-3
4.19.5	Radiological Survey Maps .....	4.19-3
4.20	K-1064 DRUM STORAGE AND BURN AREA .....	4.20-1
4.20.1	Physical Description/Survey Setup .....	4.20-1
4.20.2	Nature and Extent of Radiological Contamination .....	4.20-1
4.20.3	Data Interpretation .....	4.20-6
4.20.4	Significance of Findings .....	4.20-6
4.20.5	Radiological Survey Maps .....	4.20-6
4.21	K-1064 DRUM DEHEADING FACILITY .....	4.21-1
4.21.1	Physical Description/Survey Setup .....	4.21-1
4.21.2	Nature and Extent of Radiological Contamination .....	4.21-1
4.21.3	Data Interpretation .....	4.21-7
4.21.4	Significance of Findings .....	4.21-7
4.21.5	Radiological Survey Maps .....	4.21-7
4.22	K-1420 OIL STORAGE AREA AND ROAD .....	4.22-1
4.22.1	Physical Description/Survey Setup .....	4.22-1
4.22.2	Nature and Extent of Radiological Contamination .....	4.22-1
4.22.3	Data Interpretation .....	4.22-7
4.22.4	Significance of Findings .....	4.22-8
4.22.5	Radiological Survey Maps .....	4.22-8
4.23	K-1421 INCINERATOR AREA .....	4.23-1
4.23.1	Physical Description/Survey Setup .....	4.23-1
4.23.2	Nature and Extent of Radiological Contamination .....	4.23-1
4.23.3	Data Interpretation .....	4.23-5
4.23.4	Significance of Findings .....	4.23-5
4.23.5	Radiological Survey Maps .....	4.23-5
4.24	K-1070-B OLD CLASSIFIED BURIAL GROUND .....	4.24-1
4.24.1	Physical Description/Survey Setup .....	4.24-1
4.24.2	Nature and Extent of Radiological Contamination .....	4.24-1
4.24.3	Data Interpretation .....	4.24-9
4.24.4	Significance of Findings .....	4.24-9
4.24.5	Radiological Survey Maps .....	4.24-9
4.25	K-1407 RUSTY'S MOUNTAIN .....	4.25-1
4.25.1	Physical Description/Survey Setup .....	4.25-1
4.25.2	Nature and Extent of Radiological Contamination .....	4.25-1
4.25.3	Data Interpretation .....	4.25-12
4.25.4	Significance of Findings .....	4.25-12
4.25.5	Radiological Survey Maps .....	4.25-13
4.26	K-1070-G BURIAL GROUND .....	4.26-1
4.26.1	Physical Description/Survey Setup .....	4.26-1

4.26.2	Nature and Extent of Radiological Contamination	4.26-1
4.26.3	Data Interpretation	4.26-3
4.26.4	Significance of Findings	4.26-3
4.26.5	Radiological Survey Maps	4.26-3
4.27	K-1099 BLAIR QUARRY	4.27-1
4.27.1	Physical Description/Survey Setup	4.27-1
4.27.2	Nature and Extent of Radiological Contamination	4.27-1
4.27.3	Data Interpretation	4.27-4
4.27.4	Significance of Findings	4.27-4
4.27.5	Radiological Survey Maps	4.27-5
4.28	K-1410 NEUTRALIZATION PITS AND K-1031 WASTE PAINT ACCUMULATION AREA	4.28-1
4.28.1	Physical Description/Survey Setup	4.28-1
4.28.2	Nature and Extent of Radiological Contamination	4.28-1
4.28.3	Data Interpretation	4.28-6
4.28.4	Significance of Findings	4.28-7
4.28.5	Radiological Survey Maps	4.28-7
4.29	K-1410 PLATING FACILITY	4.29-1
4.29.1	Physical Description	4.29-1
4.29.2	Nature and Extent of Radiological Contamination	4.29-1
4.29.3	Data Interpretation	4.29-9
4.29.4	Significance of Findings	4.29-9
4.29.5	Radiological Survey Maps	4.29-9
4.30	K-1066-D AREA	4.30-1
4.30.1	Physical Description/Survey Setup	4.30-1
4.30.2	Nature and Extent of Radiological Contamination	4.30-1
4.30.3	Data Interpretation	4.30-4
4.30.4	Significance of Findings	4.30-4
4.30.5	Radiological Survey Maps	4.30-4
4.31	K-1004-L UNDERGROUND TANKS	4.31-1
4.31.1	Physical Description/Survey Setup	4.31-1
4.31.2	Nature and Extent of Radiological Contamination	4.31-1
4.31.3	Data Interpretation	4.31-4
4.31.4	Significance of Findings	4.31-5
4.31.5	Radiological Survey Maps	4.31-5
4.32	K-25 BUILDING AREA	4.32-1
4.32.1	Physical Description/Survey Setup	4.32-1
4.32.2	Nature and Extent of Radiological Contamination	4.32-1
4.32.3	Data Interpretation	4.32-19
4.32.4	Significance of Findings	4.32-19
4.32.5	Radiological Survey Maps	4.32-19
4.33	K-832-H COOLING TOWER BASIN	4.33-1
4.33.1	Physical Description/Survey Setup	4.33-1
4.33.2	Nature and Extent of Radiological Contamination	4.33-1
4.33.3	Data Interpretation	4.33-7
4.33.4	Significance of Findings	4.33-7
4.33.5	Radiological Survey Data Maps	4.33-7

4.34	K-29 RECIRCULATING COOLING WATER LINE	4.34-1
4.34.1	Physical Description/Survey Setup	4.34-1
4.34.2	Nature and Extent of Radiological Contamination	4.34-1
4.34.3	Data Interpretation	4.34-4
4.34.4	Significance of Findings	4.34-4
4.34.5	Radiological Survey Maps	4.34-4
4.35	K-27 RECIRCULATING COOLING WATER LINE	4.35-1
4.35.1	Physical Description/Survey Setup	4.35-1
4.35.2	Nature and Extent of Radiological Contamination	4.35-1
4.35.3	Data Interpretation	4.35-5
4.35.4	Significance of Findings	4.35-5
4.35.5	Radiological Survey Maps	4.35-5
4.36	K-762 SWITCHYARD AREA	4.36-1
4.36.1	Physical Description/Survey Setup	4.36-1
4.36.2	Nature and Extent of Radiological Contamination	4.36-1
4.36.3	Data Interpretation	4.36-5
4.36.4	Significance of Findings	4.36-5
4.36.5	Radiological Survey Maps	4.36-5
4.37	K-792 SWITCHYARD	4.37-1
4.37.1	Physical Description/Survey Setup	4.37-1
4.37.2	Nature and Extent of Radiological Contamination	4.37-1
4.37.3	Data Interpretation	4.37-10
4.37.4	Significance of Findings	4.37-11
4.37.5	Radiological Survey Maps	4.37-11
4.38	K-861 COOLING TOWER BASIN	4.38-1
4.38.1	Physical Description/Survey Setup	4.38-1
4.38.2	Nature and Extent of Radiological Contamination	4.38-1
4.38.3	Data Interpretation	4.38-5
4.38.4	Significance of Findings	4.38-5
4.38.5	Radiological Survey Maps	4.38-5
4.39	K-892-G/K-892-H COOLING TOWER BASINS	4.39-1
4.39.1	Physical Description/Survey Setup	4.39-1
4.39.2	Nature and Extent of Radiological Contamination	4.39-1
4.39.3	Data Interpretation	4.39-12
4.39.4	Significance of Findings	4.39-12
4.39.5	Radiological Survey Data Maps	4.39-12
4.40	K-892-J COOLING TOWER BASIN	4.40-1
4.40.1	Physical Description/Survey Setup	4.40-1
4.40.2	Nature and Extent of Radiological Contamination	4.40-1
4.40.3	Data Interpretation	4.40-6
4.40.4	Significance of Findings	4.40-6
4.40.5	Radiological Survey Maps	4.40-6
4.41	K-33 AREA	4.41-1
4.41.1	Physical Description/Survey Setup	4.41-1
4.41.2	Nature and Extent of Radiological Contamination	4.41-1
4.41.3	Data Interpretation	4.41-4
4.41.4	Significance of Findings	4.41-4

4.41.5	Radiological Survey Maps .....	4.41-4
4.42	K-822-B RECIRCULATING COOLING WATER LINES AND COOLING TOWER .....	4.42-1
4.42.1	Physical Description/Survey Setup .....	4.42-1
4.42.2	Nature and Extent of Radiological Contamination .....	4.42-1
4.42.3	Data Interpretation .....	4.42-3
4.42.4	Significance of Findings .....	4.42-3
4.42.5	Radiological Survey Maps .....	4.42-3
4.43	K-1070-C CLASSIFIED BURIAL GROUND .....	4.43-1
4.43.1	Physical Description/Survey Setup .....	4.43-1
4.43.2	Nature and Extent of Radiological Contamination .....	4.43-1
4.43.3	Data Interpretation .....	4.43-6
4.43.4	Significance of Findings .....	4.43-6
4.43.5	Radiological Survey Maps .....	4.43-6
4.44	K-1070-D CLASSIFIED BURIAL GROUND .....	4.44-1
4.44.1	Physical Description/Survey Setup .....	4.44-1
4.44.2	Nature and Extent of Radiological Contamination .....	4.44-1
4.44.3	Data Interpretation .....	4.44-14
4.44.4	Significance of Findings .....	4.44-14
4.44.5	Radiological Survey Maps .....	4.44-14
4.45	SW-31 AREA .....	4.45-1
4.45.1	Physical Description .....	4.45-1
4.45.2	Nature and Extent of Radiological Contamination .....	4.45-1
4.45.3	Data Interpretation .....	4.45-4
4.45.4	Significance of Findings .....	4.45-4
4.45.5	Radiological Survey Maps .....	4.45-4
4.46	POWERHOUSE AREA .....	4.46-1
4.46.1	Physical Description/Survey Setup .....	4.46-1
4.46.2	Nature and Extent of Radiological Contamination .....	4.46-1
4.46.3	Data Interpretation .....	4.46-19
4.46.4	Significance of Findings .....	4.46-19
4.46.5	Radiological Survey Maps .....	4.46-19
4.47	K-31 AREA .....	4.47-1
4.47.1	Physical Description/Survey Setup .....	4.47-1
4.47.2	Nature and Extent of Radiological Contamination .....	4.47-1
4.47.3	Data Interpretation .....	4.47-4
4.47.4	Significance of Findings .....	4.47-4
4.47.5	Radiological Survey Maps .....	4.47-4
5.	DATA ASSESSMENT .....	5-1
5.1	DATA QUALITY OBJECTIVES .....	5-1
5.1.1	Summary of Data Quality Objectives .....	5-1
5.1.2	Data Quality Indicators .....	5-2
5.2	DATA VALIDATION .....	5-5
5.2.1	Rationale for Validation Package Selection .....	5-6
5.2.2	Data Validation Results .....	5-8
5.3	OVERALL EVALUATION OF DATA USABILITY .....	5-10

5.4	SUMMARY AND EXPLANATION OF ANALYTICAL RESULTS .....	5-11
5.5	LESSONS LEARNED (RECOMMENDATIONS FOR IMPROVING SURVEYING TECHNIQUES) .....	5-11
6.	REFERENCES .....	6-1
APPENDIX A:	INDIVIDUAL INSTRUMENT TRACK MAPS AND BIASED SURVEY TRACK MAPS	
APPENDIX B:	SURVEY INSTRUMENT RESPONSE CHARACTERISTICS AND RESPONSE LOGS	
APPENDIX C:	FIELD CHANGE ORDERS	
APPENDIX D:	CIVIL SURVEY MAPS	
APPENDIX E:	ENHANCED GRAPHICS PACKAGE WITH USER'S GUIDE	
APPENDIX F:	SAMPLE REFERENCE TABLE	
APPENDIX G:	SOIL ANALYTICAL DATA (PROCESSED)	
APPENDIX H:	SOIL ANALYTICAL DATA (UNPROCESSED)	
APPENDIX I:	CHEMRAD TENNESSEE CORPORATION QUALITY ASSURANCE AND QUALITY CONTROL PLAN	

# 1. INTRODUCTION

An outdoor radiological characterization survey was conducted from May 23 through October 7, 1994, at 67 inactive waste sites on the Oak Ridge K-25 Site. This survey was conducted for Martin Marietta Energy Systems, Inc. (Energy Systems), operating contractor for the U.S. Department of Energy's (DOE's) Oak Ridge Reservation. The project was conducted by CDM Federal Programs Corporation (CDM Federal) and its team of specialty subcontractors—Chemrad Tennessee Corporation (Chemrad) for radiological surveying services; PEER Consultants, P.C. (PEER), for support in soil sampling and report preparation; Lockheed Analytical Services (Lockheed) for surface soil analysis; and Environmental Standards, Inc. (ESI), for data validation services.

The project scope of work consisted of performing a radiological screening survey of each site using the Ultrasonic Ranging and Data System (USRADS), identifying any areas of elevated radioactivity, collecting biased surface-soil samples from those areas, collecting systematic surface-soil samples, and conducting radioisotopic characterization of the soil samples. The fieldwork was conducted in accordance with the procedures described in the *Field Sampling Plan for the Outdoor Radiological Characterization of Inactive Waste Sites at the Oak Ridge K-25 Site*, K/ER-163 (Energy Systems 1994a), referred to hereafter as the Field Sampling Plan (FSP).

This report presents the information collected and data generated during the radiological characterization survey. Table 1.1 presents an annotated outline/report directory to assist in locating specific information provided within this report.

Table 1.1. Annotated outline/report directory

Volume	Section	Information
I	1.	<b>Introduction</b> —An overview of the project objective and approaches implemented to meet the objective.
I	2.	<b>Characterization Procedures</b> —A presentation of the radiological survey, soil sampling, and analytical procedures used, including discussions of measures taken to ensure quality control.
I	3.	<b>Soil Contamination</b> —A discussion of the soil contamination guidelines used and the risk-based limits from which they were derived.
I & II	4.	<b>Site-Specific Characterization</b> —A site-by-site presentation of survey and soil-sampling results.
II	5.	<b>Data Assessment</b> —A discussion of data quality objectives and how they were met, a summary of problems encountered and how they were resolved, and a description of data validation.
II	6.	References
III & IV	Appendix A	Individual Instrument Track Maps and Biased Survey Track Maps
V	Appendix B	Survey Instrument Response Characteristics and Response Logs

Table 1.1 (continued)

Volume	Section	Information
V	Appendix C	Field Change Orders
V	Appendix D	Civil Survey Maps
V	Appendix E	Enhanced Graphics Package with User's Guide
V	Appendix F	Sample Reference Table
VI	Appendix G	Soil Analytical Data (Processed)
VI	Appendix H	Soil Analytical Data (Unprocessed)
VI	Appendix I	Chemrad Tennessee Corporation Quality Assurance and Quality Control Plan

## 1.1 OBJECTIVE

The purpose of the radiological characterization survey was to screen inactive waste sites at the K-25 Site for radioactivity, to identify areas of elevated radioactivity, and to analyze surface-soil samples from these areas to characterize the nature and extent of any radiological contamination within the boundary of each site. The survey was performed to fulfill the radiation survey requirements of DOE Tiger Team Finding IWS/CF4, "Inactive Waste Site Identification and Characterization," Action 4, which mandated additional preliminary assessments and radiation surveys of inactive waste sites that potentially require further characterization. The K-25 Site Environmental Restoration (ER) Program will use the results of this screening survey to designate sites that require further characterization.

## 1.2 APPROACH TO RADIOLOGICAL CHARACTERIZATION

The radiological characterization survey was conducted at 67 inactive waste sites constituting ~240 acres (97 ha). Because of the proximity of the 67 sites, some were combined, forming 47 sites. Table 1.2 lists the surveyed sites according to their priority based on the Resource Conservation and Recovery Act (RCRA) Facility Investigation Plan Listing Criteria. Initially, each site was characterized qualitatively using radioactivity-measuring equipment combined with a positioning system (USRADS). Information obtained from this survey was used to characterize the site quantitatively by collecting biased surface-soil samples from areas of concern, analyzing the samples using alpha spectrometry and gamma spectrometry, and testing the samples for the presence of the beta-emitting isotope  $^{99}\text{Tc}$ . Analytical results were compared with Energy Systems soil-concentration guidelines for radionuclides to distinguish sites that may require further action.

### 1.2.1 Qualitative Approach—Radiological Survey

USRADS was used to correlate survey-instrument data automatically with the geographic locations at which they were obtained. USRADS incorporates three technologies: (1) radio

frequency (RF) communications, which are used for system timing and data transfer; (2) ultrasonics, which are used to determine distance by the propagation time of an electronic signal; and (3) microcomputers, which calculate distances and collect, display, store, and reduce data.

**Table 1.2. Sites (in order of priority) characterized during the Radiological Survey of Inactive Waste Sites at the K-25 Site**

Operable Unit	Inactive Waste Site
A	K-1131 Neutralization Pile
B	K-1232 Chemical Recovery Facility (Lagoon Area) <sup>a</sup>
C	K-631 Contaminated Soil
D	OU K-901 <ol style="list-style-type: none"> <li>1 K-1070-A Landfarm</li> <li>2 K-1070-A Old Contaminated Burial Ground</li> <li>3 K-895 Cylinder Destruct Facility</li> <li>4 K-901-A Holding Pond</li> <li>5 K-901-A North Waste Disposal Area</li> <li>6 K-901-A South Waste Disposal Area</li> <li>7 K-1070-F Construction Spoil Area<sup>b</sup></li> <li>8 Duct Island Road<sup>a</sup></li> </ol>
E	OU K-770 <ol style="list-style-type: none"> <li>1 K-770 Scrap Metal Yard</li> <li>2 K-770 Contaminated Debris</li> <li>3 K-709 Switchyard</li> <li>4 K-710 Sludge Beds and Imhoff Tanks</li> <li>5 Fercleve/Thompson Roads Gas Station</li> <li>6 1251 Old Barge Area<sup>a</sup></li> <li>7 New Barge Area<sup>a</sup></li> </ol>
F	OU K-1085 <ol style="list-style-type: none"> <li>1 Old Firehouse Burn Area and Rubble Pile<sup>c</sup></li> <li>2 Burn Pit Area<sup>c</sup></li> </ol>
G	K-1070 Rubble Pile (K-25 Site Demolition Materials Placement Area) <sup>a</sup>
H	OU K-1064 <ol style="list-style-type: none"> <li>1 Drum Storage and Burn Area</li> <li>2 Drum Deheading Facility</li> </ol>
I	OU K-1420 <ol style="list-style-type: none"> <li>1 Oil Storage Area</li> <li>2 K-1421 Incinerator Area</li> <li>3 K-1420 Road (Process Lines)</li> </ol>
J	OU K-1407 <ol style="list-style-type: none"> <li>1 K-1070-B Old Classified Burial Ground</li> <li>2 K-1407-C Soil (includes K-1417)</li> </ol>
K	K-1070-G Burial Ground <sup>a</sup>
L	K-1099 Blair Quarry <sup>a</sup>

Table 1.2 (continued)

Operable Unit	Inactive Waste Site
M	OU K-1410 1 Neutralization Pits 2 Plating Facility 3 K-1031 Waste Paint Accumulation Area 4 K-1066-D <sup>a</sup>
N	OU K-1004 4 K-1004-L Underground Tanks
P	OU K-25 1 K-311 <sup>a</sup> 2 K-304 <sup>a</sup> 3 K-305 <sup>a</sup> 4 K-306 <sup>a</sup> 5 K-303 <sup>a</sup> 6 K-309 <sup>a</sup> 7 K-310 <sup>a</sup> 8 K-302 <sup>a</sup> 9 K-312 <sup>a</sup>
Q	OU K-29/K-27 1 K-832-H Cooling Tower Basin 2 K-29 Building <sup>a</sup> 3 K-27 Building <sup>a</sup>
R	OU K-33 1 K-33 Recirculating Cooling Water Lines 2 K-762 Switchyard 3 K-792 Switchyard 4 K-861 Cooling Tower Basin <sup>a</sup> 5 K-892-G Cooling Tower Basin <sup>a</sup> 6 K-892-H Cooling Tower Basin <sup>a</sup> 7 K-892-J Cooling Tower Basin <sup>a</sup> 8 K-33 Building <sup>a</sup>
S	K-822-B Recirculating Cooling Water Lines and Cooling Tower <sup>b</sup>
U	K-1070 Classified Burial Ground 1 K-1070-C 2 K-1070-D 3 SW31 <sup>a</sup>
V	Powerhouse Area 1 K-705 <sup>a</sup> 2 K-706 <sup>a</sup> 3 K-702 <sup>a</sup> 4 K-704 <sup>a</sup>
W	K-31 Building <sup>a</sup>

<sup>a</sup> Stand alone site; not normally part of an OU<sup>b</sup> Not normally part of the assigned OU<sup>c</sup> Normally part of OU K-770

Survey instruments were channeled through USRADS to collect beta, gamma, and dose rate measurements across each site during the systematic survey. The resulting data were used to develop track maps and, ultimately, contour maps, which indicated areas of concern. The surveyor returned to each grid containing an area of concern to conduct a biased survey. The biased survey consisted of a 60-second measurement of activity over each designated area of concern. In each grid, pin flags were placed at as many as five locations at which activity measurements exceeded NaI and/or pancake probe thresholds (i.e., twice the mean reading obtained using the instrument within that grid). A pin flag also was placed at the grid's approximate center to indicate a systematic sampling location. These flags serve to guide subsequent soil-sampling activities. Using the survey results, the extent of radiological activity exceeding probe thresholds within site boundaries was determined and plotted on maps.

### 1.2.2 Quantitative Approach—Surface Soil Sampling

Within a few days of completion of the radiological survey, a sampling team revisited each grid to collect biased and systematic surface-soil samples for laboratory analysis. As many as five biased samples and typically one systematic sample of surface soil were collected within each grid. Each sample was evaluated for isotopic uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ), neptunium ( $^{237}\text{Np}$ ), technetium ( $^{99}\text{Tc}$ ), isotopic plutonium ( $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ), isotopic thorium ( $^{228}\text{Th}$ ,  $^{230}\text{Th}$ ,  $^{232}\text{Th}$ ), and cesium ( $^{137}\text{Cs}$ ). Table 1.3 identifies the type of radiation emitted and half-life for each of these isotopes.

Table 1.3. Radiation and half-life of radioisotopes analyzed for surface soils

Radioisotope	Radiation	Half-life (years)
$^{99}\text{Tc}$	beta	$2.12 \times 10^5$
$^{234}\text{U}$	alpha	$2.45 \times 10^5$
$^{235}\text{U}$	alpha, gamma	$703.8 \times 10^6$
$^{238}\text{U}$	alpha, gamma	$4.51 \times 10^9$
$^{238}\text{Pu}$	alpha	87.74
$^{239}\text{Pu}$	alpha	$2.4119 \times 10^4$
$^{240}\text{Pu}$	alpha	$6.563 \times 10^3$
$^{228}\text{Th}$	alpha, gamma	1.9131
$^{230}\text{Th}$	alpha, gamma	$7.538 \times 10^4$
$^{232}\text{Th}$	alpha, gamma	$1.405 \times 10^{10}$
$^{237}\text{Np}$	alpha, gamma	$2.14 \times 10^6$
$^{137}\text{Cs}$	beta, gamma	30.1

The nature of radiological contamination in each area was established by subtracting background soil concentrations from the soil analytical results, then comparing the results with soil contamination guidelines for radionuclides (Energy Systems 1992a). The background concentrations were obtained from the *Final Report on the Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee: Volume 1—Results of Field Sampling Program* (DOE 1993), in which naturally occurring concentrations of constituents in soils within

the Oak Ridge area were determined. The soil contamination guidelines were derived from use of the RESRAD computer program, in accordance with the requirements of DOE Order 5400.5. These guidelines were to apply to DOE-owned land to which the public has access; they are based on the 100-mrem/year DOE dose limit for a member of the public. The Energy Systems guidelines and information about the program from which they were derived are presented in detail in Sect. 3.

Residual concentrations of radioactive materials in soil are defined as those in excess of background concentrations. To characterize each site using Energy Systems radionuclide guidelines calculated by the RESRAD program, background soil concentrations were subtracted from the measured soil concentration to obtain the residual concentration in pCi/g. The background concentrations used in these calculations are presented in Table 1.4, and were obtained from the *Final Report on Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE 1993). They are the median concentrations obtained in samples from the Chickamauga Formation.

Table 1.4. Background soil radioisotope levels for the Chickamauga Formation  
(underlying the K-25 Site)

Radionuclide	Background level (pCi/g)
$^{137}\text{Cs}$	1.09E + 00
$^{237}\text{Np}$	9.28E - 02
$^{238}\text{Pu}$	7.25E - 02
$^{239}\text{Pu}/^{240}\text{Pu}$	2.40E - 02
$^{99}\text{Tc}$	1.11E + 00
$^{228}\text{Th}$	1.13E + 00
$^{230}\text{Th}$	1.04E + 00
$^{232}\text{Th}$	1.10E + 00
$^{234}\text{U}$	1.22E + 00
$^{235}\text{U}$	5.83E - 02
$^{238}\text{U}$	1.22E + 00

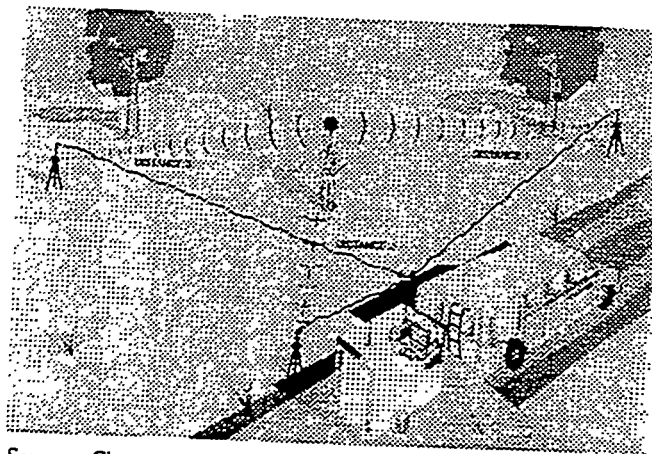
To assess the combined effect of several radioisotopes in the soil, the ratio of the residual radioisotope concentration to the Energy Systems guideline was calculated. If the sum of a sample's activity ratios was greater than the Energy Systems guideline of 1.0, then that soil was considered contaminated.

## 2. RADIOLOGICAL CHARACTERIZATION PROCEDURES

### 2.1 RADIOLOGICAL SURVEY PROCEDURES

#### 2.1.1 Description of the Ultrasonic Ranging and Data System

During the walkover radiological survey, USRADS was used to correlate survey-instrument data automatically with the geographic location at which they were obtained. The USRADS survey team consisted of a minimum of two Chemrad personnel. One person (designated as surveyor) performed the actual walkover wearing a backpack containing radiation-surveying instruments and electronic data-gathering and positioning equipment (the "Data Pack"). A second person (designated as operator) operated a mobile base station consisting of a host microcomputer and a "Master Receiver." The data, routed to the Data Pack, were transmitted from Stationary Receivers to the base station Master Receiver via RF once each second. Figure 2.1 presents a diagram of the basic system operations.



Source: Chemrad Tennessee Corporation

Fig. 2.1. Basic system operational diagram

USRADS incorporates three technologies: (1) RF communications, which are used for system timing and data transfer; (2) ultrasonics, which are used to determine distance by propagation time of an electronic signal; and (3) microcomputers, which are used to calculate distances and to collect, display, store, and reduce data.

USRADS uses an ultrasonic signal emitted from the surveyor's Data Pack at 1-second intervals. At precisely the same instant that the ultrasonic signal is emitted, an RF transmission is broadcast from the surveyor's Data Pack to the Master Receiver. Because RF transmissions travel at the speed of light, the RF transmission is used to mark the beginning of the electronic signal.

Each Stationary Receiver has an ultrasonic receiver and an RF transmitter. When a Stationary Receiver hears and identifies an ultrasonic signal emitted from the Data Pack, it transmits an RF signal to the Master Receiver. When this RF signal is received by the Master Receiver, it is used as a "stop signal" for that specific Stationary Receiver, thus establishing the time of flight of the ultrasonic signal from the Data Pack to that Stationary Receiver's location. The microcomputer then

can determine the distance between the surveyor and that Stationary Receiver. Because each Stationary Receiver responds to the ultrasonic signal, these corresponding "stop signals" are used to calculate distances. By this method, the surveyor's exact location is established each second throughout the walkover.

The USRADS software automatically and instantaneously correlates the collected instrument data with the correct location of the surveyor. The location and corresponding data values then are plotted on a grid map displayed on the host microcomputer.

During the survey, the data for each 1-second time period are posted at the top of the host microcomputer screen. The plotted position remains on the computer screen while the collected data are replaced each second to conserve screen space for plotting the track of the surveyor. At any time during the survey, the operator may view the surveyor's track line on-screen to determine if any areas have been missed during the walkover. The surveyor then may return to any missed areas to obtain the necessary coverage.

When proper survey coverage has been obtained, the operator implements the data reduction routines on the host microcomputer. Several different software routines are present, enabling the operator to review coverage and identify anomalies or other points of interest.

### 2.1.2 Instrumentation

#### Portable Survey Instruments

The walkover radiological survey was conducted using the following three instruments.

1. A Model 44-2 1-in.  $\times$  1-in. sodium-iodide (NaI) scintillation crystal-type detector probe was combined with a Ludlum Model 3 count-rate meter for near-surface gamma detection. The probe was suspended from a hinged boom proximal to the surface. The hinged boom permitted the detector to swing in a path  $\sim$ 3 ft wide while the surveyor transected the survey area. The instrument output was routed to the Data Pack so that the signal was generated simultaneously with the USRADS signal.
2. A Ludlum Model 44-9 open-window Geiger-Müller (GM) "pancake" detector mounted to the previously indicated NaI probe (see Item 1) was combined with a Ludlum Model 3 count-rate meter for near-surface beta/gamma detection. The instrument output was routed to the Data Pack so that the signal was generated simultaneously with the USRADS signal.
3. Low-level gamma exposure rate was measured by the Bicron MicroRem Model Tissue Equivalent Survey Meter. The Bicron survey meter was used to measure low-level tissue-equivalent (energy independent) dose rate in mrem/hour. The Bicron survey meter was attached directly to the hinged boom at  $\sim$ 3 ft from the ground surface. The instrument output was routed to the Data Pack so that the signal was generated simultaneously with the USRADS signal.

Detection limits for each type of detector are provided in Table 2.1. Additional information concerning calibration, response checks, and minimum detectable activity (MDA) is provided in Appendix B.

Table 2.1. Detection limits for radiological surveying instruments

Instrument type	Minimum detectable activity	Calibration source
Ludlum 44-9	2,512 dpm/100 cm <sup>2</sup>	<sup>99</sup> Tc
Ludlum 44-9	952 dpm/100 cm <sup>2</sup>	<sup>137</sup> Cs
Ludlum 44-37	145 dpm/100 cm <sup>2</sup>	<sup>99</sup> Tc
Ludlum 44-37	42 dpm/100 cm <sup>2</sup>	<sup>137</sup> Cs
Ludlum 44-2	170,000 cpm/mR/hour	<sup>137</sup> Cs
Bicron MicroRem	0.5 to 1 $\mu$ rem/hour	<sup>137</sup> Cs

### RADCART® Mounted Survey Instrumentation

The use of the RADCART® was used at several sites located near aboveground or near-surface sources of radioactivity, such as cylinder yards. Because levels of radiation at these sites are significantly higher than at other sites, it is difficult to obtain discrete measurements that reflect activity solely from the soil beneath the instrument. The RADCART® is equipped with a "shielded cone" to provide readings less susceptible to gamma radiation emitted from the radioactive material stored in the cylinders. For those surveys, four different instruments were interfaced with USRADS and confined to a three-wheeled cart to allow the use of shielding during the survey. Figure 2.2 shows the RADCART® equipped with the following survey instruments.

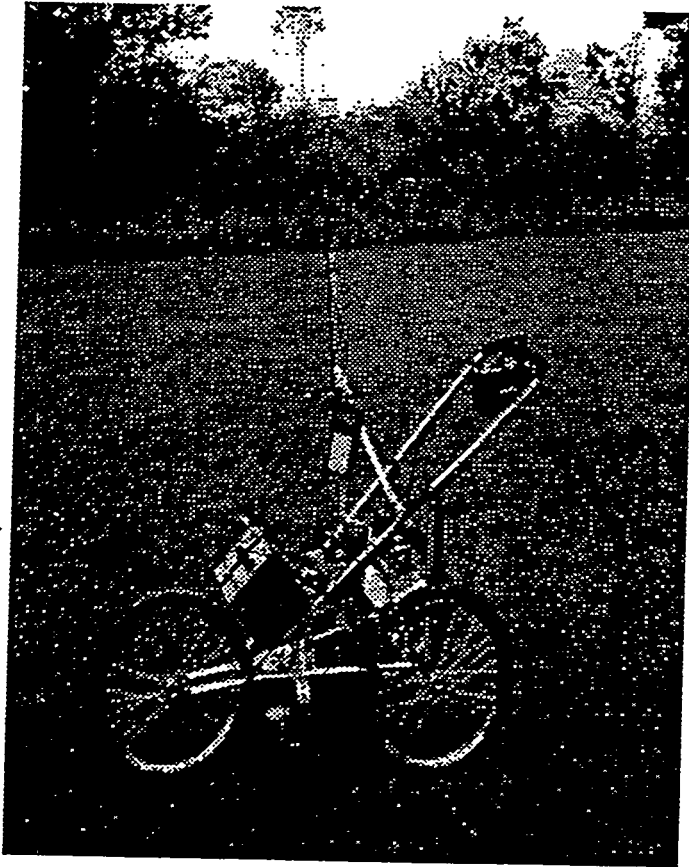
1. Two Ludlum Model 3 count-rate meters, each combined with a Ludlum Model 44-2 NaI scintillation-crystal probe, were used for near-surface gamma detection. One probe was mounted in a shielded cone (and will be referred to herein as the shielded probe); the other probe was mounted in an unshielded assembly just to the rear of the shielded probe (and will be referred to herein as the unshielded probe). Each of the probes was mounted ~6 in. above ground surface.
2. A Ludlum Model 3 count-rate meter, equipped with a Ludlum Model 44-9 "pancake" detector (referred to herein as the pancake probe) for near-surface beta/gamma detection, also was interfaced with USRADS and mounted just ahead of the shielded probe at ~3.5 in. above grade.
3. A Bicron MicroRem survey meter was interfaced with USRADS and mounted just to the rear of the shielded probe at ~3 ft above grade.

### RADMULE® Vehicle-Mounted Survey Instrumentation

The RADMULE® is an all-terrain vehicle that was used in larger, open areas, and was equipped with

1. three Ludlum Model 3 count-rate meters equipped with Ludlum Model 44-2 NaI scintillation-crystal probes, for near-surface gamma detection;

®RADCART and RADMULE are registered trademarks of Chemrad Tennessee Corporation, Oak Ridge, Tennessee.



Source: Chemrad Tennessee Corporation

Fig. 2.2. RADCART®

2. two Ludlum Model 12 detectors equipped with Ludlum Model 44-37 gas-flow-proportional floor monitors, for near-surface beta detection; and
3. a Bicron MicroRem survey meter for low-level, tissue-equivalent dose rate measurements.

USRADS is capable of processing as many as six independent channels of data each second. For the RADMULE®, these six channels of data are transmitted from three NaI scintillation crystal probes, two gas-flow-proportional floor monitors, and a dose rate meter. The actual distance between each of these instruments and the positioning crystal on the RADMULE® is used to separate the six channels of data during processing so that a single track map is produced for each type of detector. For example, a track map for the NaI probes will display the path and data recorded for each of the three instruments, providing thorough survey coverage. Figure 2.3 shows the RADMULE® fully equipped with survey instruments.

### 2.1.3 Survey Procedures

The first step in initializing the USRADS survey consisted of establishing the survey grid and referencing that grid to the K-25 Site or Powerhouse Grid Coordinate System. The survey typically was conducted over grids of  $\sim 200 \times 200$  ft ( $\sim 60 \times 60$  m); however, grid sizes and dimensions varied to meet specific survey-area conditions. The areas were surveyed using two different methods: (1) a

systematic walkover survey for beta and gamma readings within a grid, combined with the measurement of beta and gamma levels at grid intersections; and (2) a biased survey of beta and gamma readings at locations where systematic survey readings exceeded predefined thresholds. From the data obtained during the systematic walkover study, a mean NaI scintillation-crystal probe reading and a mean pancake probe reading were calculated for each grid. Threshold values then were set for each grid at twice the mean values for that grid. Locations within the grid at which an instrument obtained a reading that met or exceeded the instruments' threshold value were designated as biased sample points. At the beginning of the survey, biased points were selected based solely on exceedances of the NaI probe threshold; however, because of the discovery early in the project of elevated beta measurements at several locations, biased survey points were designated for locations having significant beta activity levels, as determined by the surveyor.



Source: Chemrad Tennessee Corporation

Fig. 2.3. RADMULE®

A systematic sampling point was set at the approximate center of each grid or, if the grid was elongated, two systematic sampling points may have been established within the grid to allow for variation within the area covered. After completing the walkover survey and determining the biased survey locations, the survey team placed pin flags at each systematic and biased sampling location, and completed a hand-drawn grid map to aid in the sampling process.

To document instrument performance during the survey, a reference point was established for each survey grid. Before and after the actual survey of each grid, a 60-second count was conducted at the reference point. In most cases, the reference point was selected at a location near one of the stationary receivers having a fixed coordinate point established by the Ogden topographic survey. The reference point data, obtained during quality and redundancy (Q&R) checks (producing Q&R files), were used to determine the net disintegrations per minute (dpm) per 100 cm<sup>2</sup> for the pancake probe. If the Q&R files were from an area of relatively low activity, the combined count time of 120 seconds was used as a local area background value. This local area background value then was used in the calculation to determine the dpm/cm<sup>2</sup>. (The location and average of the data collected are noted in the legends of contour maps provided for each site.) A maximum of  $\pm 20\%$  variation from the mean of the 60-second count at the beginning of the survey to the mean at the end of the survey was considered acceptable; if the variation was outside the acceptable range, then the grid was resurveyed after the equipment was repaired or replaced.

The radiological survey was conducted using three instruments simultaneously in a single walkover/driveover of each survey grid. Each grid was traversed at  $\sim 2.5$  ft/second, on parallel tracks spaced  $\sim 5$  ft from center to center during walkover surveying and spaced  $\sim 3$  ft from center to center during RAD CART<sup>®</sup> surveying. The RAD MULE<sup>®</sup> traversed the survey grid at  $\sim 4$  ft/second in parallel tracks  $\sim 3$  ft from center to center. Systematic surveys typically were conducted by the following process.

1. The survey crew arrived at the site.
2. The site was analyzed to determine the best deployment of survey equipment and Stationary Receivers.
3. Stationary Receivers were deployed in a configuration suitable for the site.
4. Stationary Receiver coordinates on fixed reference points (grid stakes) were entered into the host microcomputer.
5. The location of Stationary Receivers were determined by performing 30-second counts at each receiver. (If all Stationary Receivers were placed on fixed reference points, then only one 30-second count was required, to determine time of flight).
6. Radiation instruments were mounted on the surveyor, RAD CART<sup>®</sup>, or RAD MULE<sup>®</sup>, and the host microcomputer was prepared for the survey.
7. A 60-second count was performed at a known point (at one of the Stationary Receivers) to record the Q&R data and establish a reference value.
8. The surveyor moved to a starting point to begin the survey.
9. After the survey was completed, the surveyor returned to the quality check point to perform a 60-second redundancy check.
10. The survey data were analyzed to determine their quality and completeness and to determine whether biased points should be established.

11. If biased surveying was required, then the surveyor moved to the designated biased-survey points and performed a 60-second, static count using beta/gamma measurement instrumentation. A known background count in cpm (the reference value for the area established during the Q&R checks) and the mean/average static count at the biased point were each then converted to dpm/100 cm<sup>2</sup> by applying the appropriate correction factors such as efficiency and probe area. The net activity in dpm/100 cm<sup>2</sup> was derived by subtracting the reference value from the mean static count. The net activity is reported as that number determined above regardless of its being a positive or a negative number. The equation is shown in Sect. 5.1.2.
12. Data were downloaded to diskettes for future processing.
13. Equipment was removed from the site.
14. The survey team proceeded to the next survey site.

#### 2.1.4 Survey Data and Maps Generated

Track maps are graphic illustrations of survey coverage during the USRADS surveys. Figure 2.4 is an example of a typical track map. During the survey, color-coded track maps are generated by the USRADS program on the host microcomputer screen. The track maps correlate the detector signals to the surveyor's location as the survey is occurring, using changing colors to designate changes in instrument readings. Threshold values are input to the software program that changes the symbols on the track map when an established threshold value is reached. The color track maps show (1) positions of the Stationary Receivers as a plus (+) symbol accompanied by the receiver number, and (2) the path taken by the surveyor as a series of small dots. For locations at which data above the grid threshold value were obtained, the surveyor's position is indicated by larger filled circles on the track maps. (Different symbols are used to indicate values outside the selected threshold.) A large, filled circle represents at least one 1-second instrument reading above the established grid threshold value. It should be noted that biased survey maps may show one or more large filled circles, although the mean of the 60-second measurement may be below the grid threshold value.

The color track maps are generated on the host microcomputer display in real time during each USRADS walkover survey. Copies of the color maps are included in Appendix A. Because the data are automatically stored in the computer, they are immediately available for analysis and review at the conclusion of the survey. The color track maps are valuable tools for identifying general trends and providing general findings while surveys are in progress. Increasing measurement values are indicated on the maps by progression on a color scale (green, blue, magenta, yellow, red). The levels associated with each color are documented on each plot. The following are contouring parameters.

Detector	Minimum contour	Contour interval
Gamma	2000 cpm	1000 cpm
Beta/gamma	125 cpm	75 cpm
Dose rate (energy independent)	5µrem/hour	4µrem/hour

USRADS  
Track Map

Site: K1410RA (A)  
Signal: NaI Probe (cpm)

Time: 13:18:41 08/24/94  
Threshold: 3796

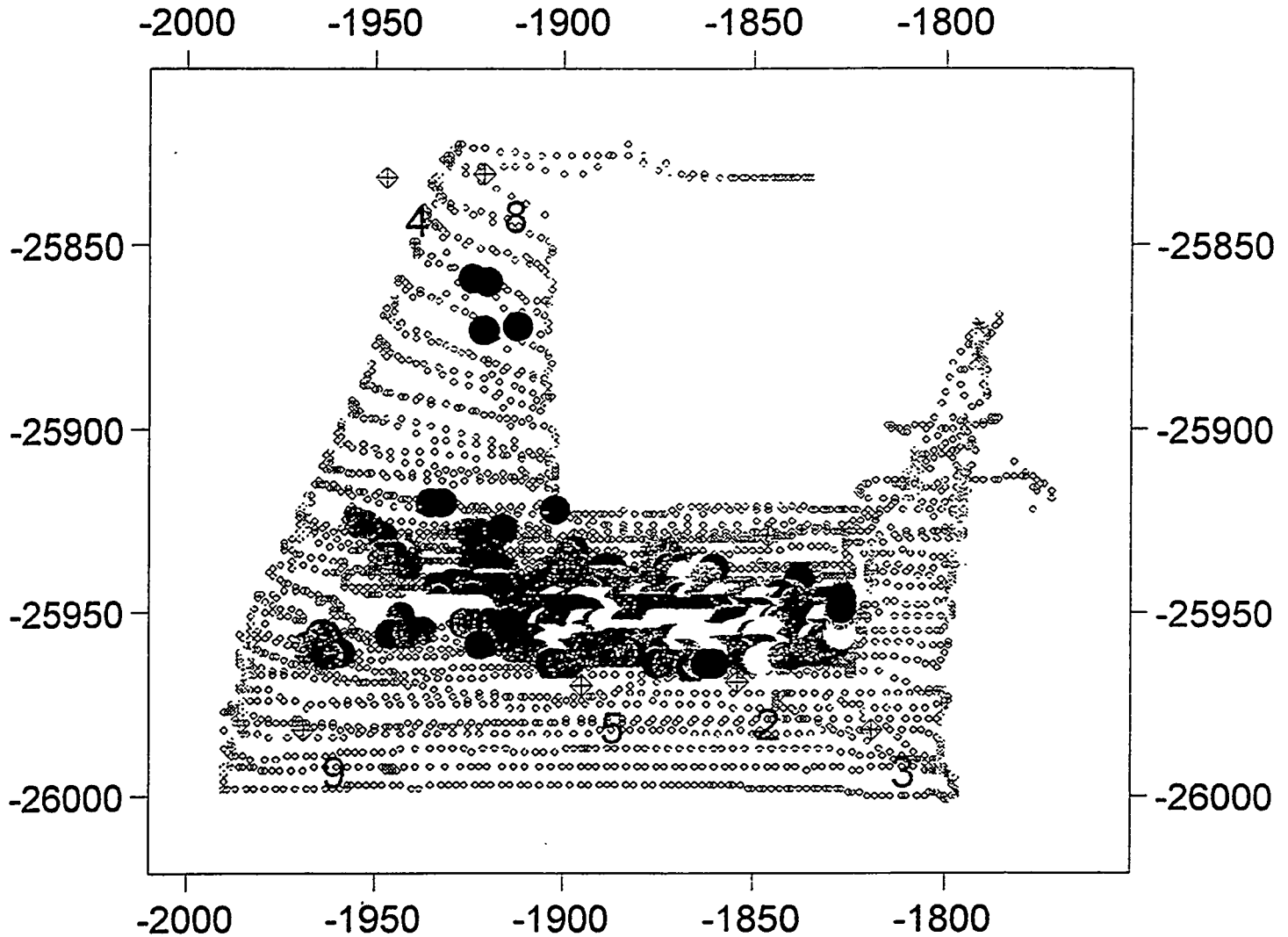


Fig. 2.4. Example of a typical radiological survey track map

Quality control checks for thoroughness of coverage, rates of radioactivity increase or decrease, clustering of color changes, and agreement of suspect findings by adjacent tracks are performed visually by the computer operator during the survey. Upon completion of the survey, the survey data are replayed on the host computer at the site to ensure site coverage.

Rate of radioactivity increase or decrease refers to the change in activity measured as the surveyor approaches and passes a radioactive source. Acceptable readings generally show a gradual change (as indicated by color codes) on adjacent tracks. Suspect readings are generally localized increases in magnitude not accompanied by a gradual increase or decrease in activity.

During the first few weeks of the radiological survey, the biased surveys were conducted only in areas in which the grid threshold value for the NaI probe was exceeded. This decision was made because available information indicated that the primary contaminants in surface soils were gamma emitters. After several sites had been surveyed, some sites were found to show high activity in a pancake probe survey, but not in a NaI probe survey. Ultimately, several areas were roped off as a result of the detection of high levels of beta activity. At this point, the radiological survey crew began conducting biased surveys based on exceedances of pancake probe thresholds as well as NaI probe thresholds. Throughout the remainder of the survey, NaI and pancake probe readings were evaluated to determine the placement of biased survey points.

Threshold values for the NaI and pancake probes were designated at a value twice the mean instrument reading across the survey grid (or the specific area surveyed for that data file). Biased surveys were conducted at a location at which the threshold value of either instrument was exceeded. Biased surveys were performed by holding the instruments for 60 seconds over the biased point. Because they were collected at the highest-reading locations, biased readings typically ranged higher than systematic-walkover readings. The mean pancake-probe reading obtained during the 60-second biased survey was corrected for area for the efficiency of the detector, and was reported in dpm/100 cm<sup>2</sup>. The equation for converting cpm to dpm/100 cm<sup>2</sup> is provided and discussed in Sect. 5.2.5. The threshold for the dose rate meter was set at 15 mrem/hour for all survey sites.

A statistical analysis of the systematic survey data was performed on a site-by-site basis, and is presented in Sect. 4 for each site. Statistical analyses were not performed for each grid within a site.

## 2.2 SOIL SAMPLING PROCEDURES

At each site, the sampling team used the site grid map and pin flags placed by the survey team to locate each sample-collection point. Each site contained at least one systematic-sampling point and as many as five biased-sampling points. Soil sampling activities were conducted in accordance with the FSP; any deviations from the sampling plan were documented on field change request forms (provided in Appendix C).

For each soil-sampling location, four 8-oz. glass jars were labeled, filled, custody-sealed, and placed in a plastic bag. Each label displayed the site-specific identification number, date of collection, analysis requested, sampler's initials, and type of preservation. Soil samples were designated by an identification number such as

## KE2-SS-B14

where

- K = the K-25 Site,
- E = Operable Unit E (as identified in Table 1.2),
- 2 = Site 2 in Operable Unit E (as identified in Table 1.2),
- SS = soil sample,
- B = biased sample (conversely, S = systematic sample),
- 1 = grid number 1,
- 4 = sample number 4 (within grid number 1).

The samples were collected from the top -6 in. of soil at the exact point indicated by the pin flag. Samples collected from a gravel surface included as much soil as could be obtained along with the gravel. Samples were mixed thoroughly and uniformly before the jars were filled. Excess soil was returned to its original location, and a disc bearing the sample identification number (in indelible ink) was attached to a survey pin driven into the ground at each sampling location. Quality control (QC) samples (e.g., rinseate blanks, field blanks, replicates) also were collected; additional information regarding the QC samples is discussed in Sect. 5.

All samples were screened for radioactivity levels to determine appropriate shipping requirements in accordance with U.S. Department of Transportation (DOT) requirements. All samples were screened by a representative from the K-25 Health Physics Department. All samples taken from the radiological contamination areas were sent to the K-25 Site Analytical Laboratory for total activity analysis. The only exception was that soil samples collected from K-631, K-1131, and K-1232 sites were taken by "Q"- or "L"-cleared personnel to the Y-12 Plant for analysis. Soil samples determined to be radioactive (i.e.,  $\geq 2000$  pCi/gm, in accordance with DOT regulations) were not sent off-site for analysis until the radioactivity was identified and quantified for the shipping manifest. Upon completion of the screening, the samples were packaged and shipped via an overnight carrier to the analytical laboratory.

## 2.3 ANALYTICAL METHODS

Each systematic, biased, and QC sample was analyzed for isotopic uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ),  $^{237}\text{Np}$ ,  $^{99}\text{Tc}$ , isotopic plutonium ( $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ , and  $^{240}\text{Pu}$ ), isotopic thorium ( $^{228}\text{Th}$ ,  $^{230}\text{Th}$ , and  $^{232}\text{Th}$ ), and  $^{137}\text{Cs}$ . Specific analytical methods used were based on U.S. Environmental Protection Agency (EPA) 900/Health and Safety Laboratory (HASL) 300 methods; Table 2.2 lists the method used for each analysis. An assessment of all data is provided in Sect. 5.

## 2.4 QUALITY CONTROL MEASURES

### 2.4.1 Radiological Survey Quality Control

#### Quality Control Measures Implemented

The following QC measures were implemented throughout the survey.

Table 2.2. Analytical methods and detection limits

Parameter	Analytical technique	Method	Matrix	Minimum detectable activity
<sup>99</sup> Tc	Liquid scintillation	DOE ESM, RP 550 <sup>a</sup>	Soil	1 pCi/g
<sup>234</sup> U, <sup>235</sup> U, <sup>238</sup> U, <sup>238</sup> Pu, <sup>239</sup> Pu, <sup>240</sup> Pu, <sup>228</sup> Th, <sup>230</sup> Th, <sup>232</sup> Th, <sup>237</sup> Np	Alpha spectrometry	HASL 300/EPA 900 series <sup>b</sup>	Soil	1 pCi/g
<sup>137</sup> Cs	Gamma spectrometry <sup>c,d</sup>	HASL 300/EPA 900 series <sup>b</sup>	Soil	1 pCi/g
QC samples (duplicates, rinseates, field blanks)	Same as target analysis	Same as target analysis	Soil/water	1 pCi/g; 1 pCi/L

<sup>a</sup>DOE 1993, Radiochemical Procedure 550 (extraction chromatography)

<sup>b</sup>Based on EPA Series 900, "Prescribed Procedures for Measurements of Radioactivity in Drinking Water."

<sup>c</sup>Modifications to HASL or EPA methods were submitted to CDM Federal for approval. (Sample preparation and separation modifications for soil matrix were required in most cases.)

<sup>d</sup>Individual isotopic quantitation was required for all elements.

1. Q&R measurements were made on each grid surveyed to ensure the reproducibility of data. If the measurements were not within the allowable margin of error ( $\pm 20\%$ ), then the cause of the difference was determined.
2. The computer operator conducted real-time, ongoing monitoring of the survey and individual data channels, to note any discrepancies in the data as quickly as possible.
3. Cross-check routines of Stationary Receiver locations were conducted to confirm the accuracy of surveyor coordinates.
4. Radiological instruments were checked daily to confirm the accuracy of data readings.
5. Generated survey data were analyzed to detect any failure of the survey routine.
6. The data processing staff reviewed and analyzed the data.
7. Project management reviewed and analyzed the processed data.

Specific QC procedures are given in Chemrad's *Quality Assurance and Quality Control Plan*, QAQC-94 (Appendix I).

### Instrument Calibration, Background, and Response Checks

Radiological survey instruments were calibrated by the manufacturer or a qualified vendor before the surveys were begun. Calibrations were coordinated by Chemrad. (Records are retained at Chemrad's Oak Ridge, Tennessee, office.) Each radiation-survey instrument received a daily response check (including battery and source checks) before it was used in the field. All daily response checks were performed at the staging site (the K-892 Pumphouse) using a <sup>137</sup>Cs source and a <sup>99</sup>Tc source. Each radiation instrument also underwent a response check at the staging area at the end of each service day to verify measurement consistency. Instruments not within the allowable margin of error ( $\pm 20\%$ ) were removed from service, and the grids on which they were used that day

were resurveyed. Detection limits of the survey instruments are provided in Table 2.1. Other survey-instrument characteristics and response logs are presented in Appendix B.

### **Field Changes Associated with Surveying Activities**

Survey procedures are described in the FSP (Energy Systems 1994a); if a different procedure was used, a field change was requested by the CDM Federal Field Task Manager (FTM) or Project Manager and approved by the Energy Systems Project Manager before implementation. Five field change orders associated with the radiological survey were issued; these are provided in Appendix C. Key elements of these field change orders are given in Table 2.3.

### **2.4.2 Soil Sampling Quality Control**

Several QC measures were implemented to ensure the integrity of the collected samples and the quality of the resulting data. This section provides a description of documentation, sample custody, QC sampling, decontamination, and field changes associated with sampling activities.

#### **Documentation of Soil Sampling Activities**

A site logbook was maintained by the FTM for the duration of the field effort. The FTM coordinated as many as four crews daily (including two radiological survey crews, a topographic survey crew, and a sampling crew). Information associated with all activities was recorded in the site logbook by the FTM or designee. Information recorded daily for all field activities included

- day, date, and time of arrival on-site;
- site location/identification;
- names, affiliations, and arrival and departure times of all personnel or visitors on-site;
- weather conditions;
- health and safety level and changes;
- log and summary of any daily field activities and significant events;
- notes of conversations with coordinating officials;
- cross references to other field logbooks or forms that contain detailed information;
- discussion of problems, issues, or concerns encountered and their resolution;
- description of unusual conditions;
- discussion of deviations from the FSP, Quality Assurance Project Plan, or other governing documents; and
- duration and cause of delays and down-time, and personnel affected.

Table 2.3. Field changes associated with K-25 Site radiological surveying activities

Date issued	Subject	Description	Justification	Prompted by an audit or surveillance?
June 9, 1994	Classification on priority of Health Physics (HP) contact for field crews	This field change provides a prioritized list of HIP names, telephone numbers, and radio numbers, along with a laminated copy of key information from Sect. 10 of the Health and Safety Plan (HASP) (Energy Systems 1994b) for quick reference.	If the field crew encountered areas of radiological contamination above posted limits, this would allow them to contact an HIP representative quickly, to permit continued progress on the survey while remaining in compliance with the HASP.	No
June 14, 1994	Use of cone shielding at five survey sites	Cone shielding was used over the NaI probe at five sites (~10-11 acres): K-631, 901-A North, K-1070, K-832-II, and K-895.	The five listed sites are adjacent to cylinder yards that produce high levels of "shine" (i.e., radioactive interference) and thereby affect survey instrument readings.	No
July 7, 1994	Anticontamination (anti-C) clothing	Anti-C clothing worn by the survey and sampling crews was not drummed for disposal after use, but was returned to a radiation-boundary-control station for transport to the laundry. Disposable personal protective equipment such as gloves, cotton liners, etc., were surveyed by K-25 Health Physics Technicians; if uncontaminated, they were disposed of as normal sanitary waste. Contaminated disposable items and used anti-C clothing were taken to a radiation-boundary control station and placed in appropriate containers.	This process avoids the waste of resources involved in unnecessary disposal of anti-C clothing, and conforms with waste minimization practices.	Yes; surveillance conducted on July 11, 1994, by J. V. Spence (Energy Systems). Finding 94K-RAD.F04.
July 19, 1994	Heat stress	Table 6.3, which provides specific guidance for the Site Health and Safety Officer in monitoring for heat stress, was added to Sect. 6 of the HASP (Energy Systems 1994b).	Potential existed for heat-related problems and injuries to field personnel during fieldwork in summer months.	No
July 20, 1994	Use of 4-wheel-drive vehicle for systematic survey at several sites	The radiological survey crew used a 4-wheel-drive vehicle (the RADMULT <sup>®</sup> ) at designated systematic and biased survey sites. The RADMULT <sup>®</sup> was equipped with two gas-flow-proportional counters and three NaI probes, all front-mounted. The RADMULT <sup>®</sup> gave approximately 100% coverage across a 3-ft-wide path. Before implementation of the RADMULT <sup>®</sup> , a demonstration was performed to compare data from a walkover survey with data gathered using the RADMULT <sup>®</sup> ; coverage from the RADMULT <sup>®</sup> survey was as thorough as, if not better than, that of the walkover survey.	The use of the vehicle lessened the risk of heat-stress-related injury to the survey crews.	No

When soil sampling activities were begun, a field logbook and bound sample logsheets were maintained by the sampling crew to document all sampling-specific information. Later, the decision was made to streamline documentation efforts and increase productivity by revising the sample logsheet to allow its use to record all information necessary to document the sampling activities. The resulting sample logsheet consisted of two pages. The first page contained information applicable to all samples collected on a given day. The second page was designated to record all information pertaining to a single sample. (Therefore, several of these "second-page" sample logsheets were completed each day.) Information recorded on the revised sample logsheet included

- date;
- weather conditions;
- name, affiliation, and title of sampling crew;
- instrument model, serial number, date of last calibration, date of next scheduled calibration, and probe type;
- comments;
- decontamination time and personnel, shovel number, spoon number, and bowl number;
- sample identification number, date and time of collection, medium, and location;
- K-25 Site or Powerhouse Coordinate System northings and eastings of sampling locations provided by USRADS;
- sample container volume, type, and analyses requested;
- personal protective equipment used;
- field background and beta/gamma measurements; and
- chain-of-custody number, cooler number, and airbill number.

All logbooks were signed and dated daily by the person recording the information; the logbooks then were reviewed for completeness and countersigned by the FTM or designee. Logbooks were assigned bar codes and document control numbers, and were tracked through the CDM Federal records/data management system. Copies of the logbooks were made at least once weekly, and were submitted to the CDM Federal Records Management Clerk to serve as a backup until the completed logbook was submitted. Documentation of field activities was performed in accordance with ESP 503.

### **Sample Custody**

To ensure that each sample was not mislabeled or mistaken for another sample, only the required number of sample containers for each soil sample was handled at any one time. Sample containers were filled with soil, labeled, custody-sealed, and placed in bubble wrap. Details of the

sampling activities were documented on sample logsheets and on the chain-of-custody forms. Samples then were placed in a small cooler. Each day (or on alternate days), samples were repacked in a large cooler together with the associated chain-of-custody form for shipment. As samples were placed in this large cooler, information on the chain-of-custody form was verified. Coolers were custody-sealed before shipment. Samples kept overnight for shipment the next day were stored and locked in the Radioactive Materials Area established at the K-25 Site for this project. Sample custody was maintained in accordance with ESP 501.

### **Quality Control Samples**

Three types of QC samples were collected to ensure that any contaminants detected at the site were not cross-contaminant products or derived from off-site sources. The QC samples collected were rinseate blanks, field blanks, and field duplicates.

**Rinseate blanks** are used to assess the effectiveness of the decontamination process for cleaning the sampling tools between sample collection events. The analysis of rinseate blanks evaluates the adequacy of the cleaning procedures, to avoid carryover of contamination from one sample to another. One rinseate blank was submitted for every ten samples collected; a total of forty-eight rinseate blanks were collected and analyzed.

**Field blanks** were collected from the potable water used in the decontamination process. One field blank was collected at the beginning and one at the end of the project.

**Field duplicates** were collected to determine whether the field sampling technique was reproducible. Duplicate sample collection involved repetition of the sample collection process for a specified sampling site. Two individual samples were collected from the same spot, using the same sampling equipment and procedures to fill separate sample containers. One field duplicate was submitted for every ten samples collected; a total of forty-five field duplicates were collected and analyzed.

### **Sampling Equipment Decontamination**

Sampling equipment was decontaminated using Liquinox™ and potable water before sample collection, as specified in the FSP. Decontamination fluids were placed in a 55-gal drum for future treatment and/or disposal by Energy Systems. Decontamination activities were documented in a waste management logbook; information recorded included volumes of fluids and associated sample-collection locations. All decontamination activities were performed in accordance with the FSP.

### **Field Changes Associated with Soil Sampling Activities**

Soil sampling activities were conducted in accordance with the FSP; if a different procedure was used, then a field change was requested by the FTM and approved by the Energy Systems Project Manager. Three field change orders were issued during the soil sampling activities; these are provided in Appendix C. Key elements of these field change orders are presented in Table 2.4.

Table 2.4. Field changes associated with K-25 Site soil-sampling activities

Date issued	Subject	Description	Justification	Prompted by an audit or surveillance?
June 2, 1994	Sample radiological screening	The FSP (Energy Systems 1994a), Sect. 4.6, p. 30, 3rd sentence, stated "[a]ll samples taken from biased contamination areas . . ." and was revised to state "[a]ll samples taken from radiological contamination areas . . ."	The intent of the original wording was to specify that only those samples collected in radiologically contaminated areas would be sent to the K-25 Site Analytical Laboratory. However, adherence to the original wording would have resulted in all biased samples remaining on-site for radioactive contamination screening to determine DOT shipping requirements.	No
June 3, 1994	Soil sample collection from classified sites	A statement was added to the FSP, Sect. 4.6, p. 20, that "[s]oil samples collected from K-631, K-1131, and K-1232 sites will be taken by 'Q' or 'L' cleared personnel to Y-12 for analysis."	This provision was made for security and classification purposes.	No
July 19, 1994	Addition of a qualifier to the sample identification number	The first entry in the last three columns of the sample identification number was changed from a zero to an "S" or "J." The "S" indicates that the sample is a systematic sample, and the "J" indicates that the sample is a biased sample.	This addition was made to allow differentiation between systematic and biased samples.	No

### 3. ENERGY SYSTEMS SOIL CONTAMINATION GUIDELINES

To characterize the nature of the radiological contamination within the gridded area at each site, soil concentration guidelines for radionuclides were used. In 1989, a manual was developed at Argonne National Laboratory (Gilbert et al. 1989) for implementing DOE's limits on residual radioactive material (based on DOE Order 5400.5), and the recommended dose-assessment methodology for deriving site-specific soil guidelines was coded within the microcomputer program RESRAD. RESRAD is reissued each time it is modified, but the guidelines used in this study were taken from a run of the 1989 version of the RESRAD program. This program (RESRAD Version 3.121) was used to develop the guidelines presented in Table 3.1. The generic guidelines for  $^{230}\text{Th}$  and  $^{232}\text{Th}$  were taken from DOE Order 5400.5.

The derived guidelines are based on the 100-mrem/year DOE dose limit for a member of the public. The parameters of interest and their associated Energy Systems guidelines were excerpted from the *Martin Marietta Energy Systems, Inc., Position Paper (Revision 0)* (Energy Systems 1992a).

Table 3.1. Energy Systems single-radionuclide soil concentration guidelines

Radionuclide	Guideline (pCi/g)
$^{137}\text{Cs}$	30
$^{237}\text{Np}$	40
$^{238}\text{Pu}$	200
$^{239/240}\text{Pu}$	200
$^{99}\text{Tc}$	70
$^{228}\text{Th}$	No guideline <sup>a</sup>
$^{230}\text{Th}$	5 <sup>a</sup>
$^{232}\text{Th}$	5 <sup>a</sup>
$^{234}\text{U}$	200
$^{235}\text{U}$	100
$^{238}\text{U}$	200

<sup>a</sup> No guideline exists for  $^{228}\text{Th}$ . Generic guidelines are used for  $^{230}\text{Th}$  and  $^{232}\text{Th}$ . Values for these three isotopes are not included in the sum of ratios.

Two criteria are used for determining if Energy Systems guidelines have been exceeded: (1) if any single radionuclide exceeds the guideline value specified for that parameter, or (2) if more than one radionuclide is present, if the sum of the activity ratios of the residual soil concentrations to the guidelines exceed 1.0. This ratio is calculated using the following equation:

where

$N$  = total number of radionuclides detected in the soil,  
 $C_i$  = measured soil concentration for the  $i^{\text{th}}$  radionuclide,  
 $G_i$  = soil concentration guideline for the  $i^{\text{th}}$  radionuclide.

### 3.1 PURPOSE OF SOIL CONTAMINATION GUIDELINES

As a result of past operations at the K-25 Site, areas of radiologically contaminated soil may exist outside controlled areas of the site. To ensure the protection of members of the public who might have access to potentially contaminated DOE-owned land, a consistent methodology is needed to identify and control environmental areas potentially containing contaminated soils. At present, no clear-cut regulatory requirement exists regarding these areas. These guidelines were developed to present the Energy Systems position on identifying, posting, and controlling such areas.

### 3.2 DEVELOPMENT OF SOIL CONTAMINATION GUIDELINES

Development of these guidelines included a review of the regulations and guidance on identification, posting, and control of areas of environmental soil contamination. Three sources were identified as generally applicable: DOE Order 5480.11, DOE Order 5400.5, and the DOE Radiological Control Manual. Of these three, DOE Order 5400.5 was chosen to serve as the basis for development of the Energy Systems guidelines because it pertains to protection of the public and the environment. The order states that site-specific soil-concentration guidelines must be derived. The following is a discussion of the assumptions and parameters used in RESRAD calculations to determine the Energy Systems soil-concentration guidelines.

The DOE model for deriving site-specific guidelines is based on release of the land for unrestricted use; therefore, land uses such as permanent habitation and gardening were assumed. To this end, the family farm scenario was used in developing the Energy Systems guidelines. This scenario assumes that a family establishes a residence in the contaminated zone after it has been released for unrestricted use, even though such release is unlikely. Use of this scenario ensures that Energy Systems soil-concentration guidelines are set so that the potential dose to a member of the public living within the contaminated zone is less than 100 mrem/year.

The pathway analysis method referred to as the "concentration factor method" was used in the model to establish a relationship between radionuclide concentrations in contaminated-zone soils and an annual dose to a member of a family living and farming within the contaminated zone. All significant exposure pathways for such a family member were considered. These pathways include

- direct exposure from contaminated soil,
- internal exposure from inhalation of airborne radionuclides,
- internal exposure from ingestion of plant foods grown in contaminated soil,
- internal exposures from ingestion of meat and milk from livestock fed contaminated feed and water,
- internal exposures from ingestion of drinking water from a contaminated well, and
- internal exposure from ingestion of fish from a contaminated pond.

The dose-to-source concentration ratio for a measured soil concentration in the contaminated zone can be used to determine the contribution to the effective dose equivalent of a specific radionuclide and pathway at a given time after the measurement. This ratio is a sum of the products of the dose conversion factors, the environmental transport factors, and the source factors for that radionuclide and pathway. These factors (calculated based on site-specific parameters input into the RESRAD program) establish the relationship between dose and radionuclide soil concentrations.

The RESRAD program was used to calculate the single-radionuclide soil-concentration guidelines that could lead to an annual dose of 100 mrem during any year from the present to 1000 years in the future. Guidelines were calculated for all target radionuclides. Target radionuclides are those that may be present on-site in quantities that could lead to detectable contamination outside the security fence. Soil concentration guidelines were calculated for  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{137}\text{Cs}$ ,  $^{237}\text{Np}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ,  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ , and  $^{241}\text{Am}$ .

Site-specific parameters were chosen based on average and reasonable conditions. The following parameters were input into RESRAD Version 3.121 to calculate the Energy Systems soil-concentration guidelines:

- a uniformly contaminated zone of approximately 1000 m<sup>2</sup> in area, 1 m in thickness, and 100 m in length (parallel to aquifer flow);
- a time horizon of 1000 years [based on the DOE Order 5400.5 methodology for long-term management of sites under the Formerly Utilized Sites Remedial Action Program (FUSRAP)];
- initial radionuclide concentrations of 1.00 pCi/g;
- a cover depth of 0 m in clay soils;
- a distance of 5 m from the surface water table;
- default RESRAD unsaturated-zone hydrological-data parameters (as listed in Energy Systems 1992a);
- the geometric mean of the distribution coefficients ( $K_d$ ) presented in the literature for clay soils;
- RESRAD defaults for external-gamma and dust-inhalation parameters; and
- RESRAD defaults for ingestion-pathway parameters.

The following are the Energy Systems soil-contamination guidelines.

**External gamma radiation**—The level of gamma radiation on open lands will not exceed the normal area background level by more than 20  $\mu\text{R}/\text{hour}$ .

**Single-radionuclide soil concentrations**—The concentration of any single radionuclide above normal background levels (i.e., residual concentration) shall not exceed the individual isotope guidelines derived using RESRAD methodology (Table 3.1). If more than one radionuclide is present, then the sum of the ratio of each residual concentration to its guideline will not exceed 1.0.

### 3.3 IMPLEMENTATION OF SOIL CONTAMINATION GUIDELINES

Areas that are outside controlled portions of Energy Systems–managed installations and that have elevated radiation levels may be identified through routine surveys, or by periodic environmental soil sampling. If survey measurements exceed twice the normal background level for the area, then the area will be considered contaminated. When such an area has been identified, Energy Systems personnel will implement the following steps to determine the area's final disposition.

1. Determine boundaries of the elevated area, and rope it off. Post the area as a "Soil Contamination Area." The area may remain at this status for as long as 60 days while the final disposition is being determined.
2. Measure the direct-radiation-exposure rate ( $\mu\text{R}/\text{hour}$ ) using an exposure-rate-monitoring instrument, and compare the results with the direct-gamma-exposure limits stated in Sect. 3.2.
3. Collect and analyze representative soil samples from the elevated area to identify the radionuclides present and their respective concentrations. Compare the results with Energy Systems' soil-concentration guidelines as shown in Table 3.1 for single radionuclides, or calculate the sum of the activity ratios of the residual soil concentrations to the guidelines.
4. Review the results of the analyses performed in Steps 2 and 3. If neither guideline has been exceeded, then no further action is required. In this case, remove the posting and roping from the area. Document the results of the surveys, the analyses, and the final disposition.
5. If either of the guidelines has been exceeded, then further action is required. Positive control must be established over the area, or else remedial action must be implemented. An acceptable method of maintaining positive control over an area is to erect a fence that is locked and posted. The area must be posted with a warning, such as "Caution—Radioactive Soil Contamination Area," in accordance with the DOE Radiological Control Manual. An alternative to positive control of the soil contamination area is the implementation of remedial action to lower the concentrations of radionuclides to a level below the guideline. In either case, the area's final disposition must be documented within 60 days after it is determined to contain elevated radiation levels. If locking and posting are used to maintain positive control over the area, then verify and document, at least annually, that the controls remain in place.

Energy Systems–managed installations will maintain written and approved procedures that ensure that these steps are implemented.

## 4. SITE-SPECIFIC CHARACTERIZATION

This section presents radiological survey data and surface-soil analytical data collected for each site. Because of the proximity of the 67 inactive waste sites, some were combined, forming 47 sites that are presented as Sects. 4.1 through 4.47. The organization of each subsection follows this example format.

### 4.1 K-1131 Neutralization Pile

- 4.1.1 Physical Description/Survey Setup
- 4.1.2 Nature and Extent of Radiological Contamination
- 4.1.3 Data Interpretation
- 4.1.4 Significance of Findings
- 4.1.5 Radiological Survey Maps

Track maps that support the radiological contour maps provided for each site are presented in Appendix A (A.1 through A.47). Surface-soil analytical data for each site are provided in Appendix G [G.1 through G.47, plus G.48 (Field Blanks)].

Each of the sites was evaluated based on radiological survey data and surface-soil analytical data. However, the criteria for determining which sites require further action was based solely on analytical data (see Sect. 3). The site evaluation determined that 16 sites require further action and 31 sites require no further action; sites requiring further action are identified in Table 4.1. Also, 22 changes were made in the posting of areas as a result of the radiological survey of these sites; Table 4.2 presents the areas and posting changes implemented and planned.

The following information applies to evaluation techniques and criteria used in conducting fieldwork and in assessing the need for further action. To condense the evaluation of each site and to avoid unnecessary repetition, this information is not repeated in each section presenting site-specific results.

- **Correlation of Data Sets.** The radiological survey provided qualitative data to be used as a screening tool to identify areas having radioactivity levels above twice the average reading from the corresponding survey grid. This information guided surface-soil-sampling activities that, in turn, provided quantitative data used to evaluate each site. No direct correlation exists between the two types of data generated, although they sometimes are coincidentally in agreement. Observations made during this project show that some systematic samples had elevated radioactivity levels and some biased samples had radioactivity levels lower than the soil contamination guidelines. Several factors could cause soil analytical results to differ from what is expected based on survey results; these include (1) sampling location, (2) soils having higher activity just below the ground surface, (3) self-absorption of radiological contaminant, (4) extensive preparation of analytical samples, (5) homogenization of samples, and (6) sensitivity and count times of laboratory equipment versus field equipment.
- **$^{230}\text{Th}$  and  $^{232}\text{Th}$  Soil Guidelines.** Isotope guidelines used for  $^{230}\text{Th}$  and  $^{232}\text{Th}$  are those generic guidelines listed in DOE Order 5400.5, whereas the other guidelines are isotope-specific. The sum of the activity ratios provides an estimation of the combined effect of the presence of all

radioisotopes using isotope-specific ratios; therefore, activity ratios for  $^{230}\text{Th}$  and  $^{232}\text{Th}$  are not calculated or included in the sum.

**Table 4.1. Sites requiring further action based on the radiological characterization of inactive waste sites**

Section	Site
4.1	K-1131 Neutralization Pile
4.2	K-1232 Chemical Recovery Facility (Lagoon Area)
4.5	K-1070-A Old Contaminated Burial Ground
4.6	K-895 Cylinder Destruct Facility
4.12	K-770 Contaminated Debris and Scrap Metal Yard
4.20	K-1064 Drum Storage and Burn Area
4.21	K-1064 Drum Deheading Facility
4.22	K-1420 Oil Storage Area and Road
4.23	K-1421 Incinerator Area
4.24	K-1070-B Old Classified Burial Ground
4.25	K-1407 Rusty's Mountain
4.28	K-1410 Neutralization Pits and K-1031 Waste Paint Accumulation Area
4.29	K-1410 Plating Facility
4.31	K-1004-L Underground Tanks
4.32	K-25 Building Area
4.44	K-1070-D Classified Burial Ground

**Table 4.2. Actions taken and planned based on results of the radiological characterization at inactive waste sites**

Area	Type of upgrade	Action taken	Action planned
K-1064	Upgraded to Contamination Area	Posting of signs	
K-1064	Upgraded to Contamination Area	Posting of signs	
K-1131	Upgraded to Contamination Area	Fencing of Soil Contamination Area, Posting: Rad Worker Permit (RWP) required for entry, Controlled Area	
K-1303 (K-1070-B)	Upgraded to Contamination Area	Posting of signs	
K-895	Upgraded to High Contamination Area	Fencing; Posting of signs	
K-1232	Upgraded to Contamination Area	Posting of signs	
K-1410	Upgraded to Contamination Area	Posting of signs	
K-1031	Upgraded to Contamination Area	Posting of signs	
K-25 East	Upgraded to Contamination Area	Posting of signs	
K-25 East	Upgraded to Contamination Area	Posting of signs	

Table 4.2 (continued)

Area	Type of upgrade	Action taken	Action planned
K-1407	Upgraded to Contamination Area	Posting of signs	
K-31	Upgraded to Contamination Area	Posting of signs	
K-31	Upgraded to Contamination Area	Posting of signs	
K-33	Upgraded to Contamination Area	Posting of signs	
K-33 East	Upgraded to Contamination Area	Posting of signs	
K-901-A North	Upgraded to Soil Contamination Area	(1) Fencing; Posting Entire Site as "Underground Radioactive Material" (2) 4 sites posted as "Controlled, RWP, Fixed Contamination, Soil Contamination"	
K-1070-A	Upgraded to Soil Contamination Area		Posting of signs
K-770	Upgraded to Soil Contamination Area		Posting of signs
K-1420	Upgraded to Soil Contamination Area		Posting of signs
K-1421	Upgraded to Soil Contamination Area		Posting of signs
K-1004-L	Upgraded to Soil Contamination Area		Posting of signs
K-1070-D	Upgraded to Soil Contamination Area		Posting of signs

- **$^{228}\text{Th}$  Soil Guidelines.** No individual isotope guideline exists for  $^{228}\text{Th}$ ; therefore, an activity ratio for  $^{228}\text{Th}$  was not calculated or included in the sum.
- **Estimated Systematic Sampling Locations.** Because determining northings and eastings for systematic samples was not a requirement, many of the systematic sampling locations are estimated, and are identified as such.
- **Dose Rate Thresholds.** The dose rate threshold for all sites was set at 15  $\mu\text{rem}/\text{hour}$ ; however, the typical instrument variation is normally 4 to 15  $\mu\text{rem}/\text{hour}$ . Therefore, many sites show exceedances of the dose rate threshold. The graphics package allows adjustment of the dose rate scale, and can be used to evaluate the dose rates measured at each site (see Appendix E).
- **Data Qualifiers.** The analytical-laboratory and data-validation qualifiers shown in Table 4.3 were applied to the surface-soil analytical results.
- **Conduct of Biased Surveys.** Initially, biased surveys were conducted only in areas where the NaI threshold value was exceeded during the systematic survey. Later, several areas having high beta activity were identified, and it was decided that such areas also should be subject to a biased survey. This did not mean, however, that a biased survey should be conducted at any area exceeding the pancake probe threshold. Although numerous sites show slightly elevated

beta-activity levels, few sites show high levels. Consequently, the decision of whether beta activity levels warranted a biased survey was left to the survey team.

**Table 4.3. Data qualifiers for radiochemical analyses**

Qualifier	Definition
<i>Lockheed Analytical Services Laboratory radiochemical analyses</i>	
B	Constituent was detected in the associated blank, and its concentration was greater than the reporting detection limit (RDL) and/or minimum detectable activity (MDA).
D	Constituent was detected in the diluted sample.
F	For alpha spectrometry only—full width half mass (shape of curve and instrument readout) exceeded acceptance limits.
Y	Chemical yield exceeded acceptance limits.
<i>Environmental Standards, Inc., data validation</i>	
U	This isotope was analyzed for but was not detected above the reported sample detection limit.
UJ	The isotope was not detected above the reported sample detection limit. However, the reported detection limit is approximate and may or may not represent the actual limit of detection necessary to accurately and precisely measure the isotope in the sample.
J	The isotope was positively identified. The associated numerical value is the approximate concentration of the isotope in the sample.